SPIRE

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PREPARED BY:	**Bruce Swinyard**		
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CHECKED BY:	**Berend Winter (MSSL)**	**Date:**
	Dominique Pouliquen (LAM)	**Date:**
	Peter Hargrave (QMW)	**Date:**
	Lionel Duband (CEA)	**Date:**
	Jamie Bock (JPL)	**Date:**
	Jean-Louis Augueres (CEA)	**Date:**
	Riccardo Cerulli-Irelli (IFSI)	**Date:**
	Gary Davis (USK)	**Date:**
	Hans-Gustav Floren (Stockholm)	**Date:**
APPROVED BY:	**Matt Griffin**	**Date:**
	Ken King	**Date:**
	Laurent Vigroux	**Date:**
	Colin Cunningham	**Date:**
	Jerry Lilienthal	**Date:**

Distribution

Matt Griffin	**Principal Investigator (QMW)**
Laurent Vigroux	**Co-Principal Investigator (CEA)**
Walter Gear	**Project Scientist**
Jean-Paul Baluteau	**Project Scientist**
Ken King	**Project Manager (RAL)**
Bruce Swinyard	**Instrument Scientist (RAL)**
Colin Cunningham	**FPU Systems Engineer (ATC)**
Jean-Louis Augueres	**CEA(Saclay)**
Lionel Duband	**CEA (Grenoble)**
Don Jennings	**GSFC**
Jerry Lilienthal	**JPL**
Jamie Bock	**JPL/Caltech**
Jason Glenn	**University of Colorado**
Dominique Pouliquen	**LAM**
Berend Winter	**MSSL**
Kjetil Dohlen	**LAM**
Peter Hargrave	**QMW**
Gary Davis	**USK**
David Smith	**RAL**
Hans-Goran Floren	**Stockholm**
Riccardo Cerulli-Irelli	**IFSI**
Anna Di Giorgio	**IFSI**

Change Record

ISSUE	DATE	
Draft	19/05/2000	First draft for comment
1	20/05/2000	Detailed changes to wording on description of DPU and DRCU QM capabilities. Version issued for Delta PDR

Table of Contents

Glossary

AIV	Assembly Integration and Verification
AOCS	Attitude and Orbit Control System
ASIC	Application Specific Integrated Circuit
AVM	Avionics Model
BSM	Beam Steering Mechanism
CDMS	Command and Data Management System (on Spacecraft)
CQM	Cryogenic Qualification Model
CVV	Cryostat Vacuum Vessel
DCRU	Detector Control and Readout Unit
DPU	Digital Processing Unit
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
FINDAS	FIRST Integrated Network and Data Archive System
FOV	Field of View
FPU	Focal Plane Unit
FS	Flight Spare
FTS	Fourier Transform Spectrometer
IID-A	Instrument Interface Document part A
IID-B	Instrument Interface Document part B
JFET	Junction Field Effect Transistor
MGSE	Mechanical Ground Support Equipment
NEP	Noise Equivalent Power
OBDH	On Board Data Handling (on Spacecraft)
OGSE	Optical Ground Support Equipment
OPD	Optical Path Difference
PDU	Power Distribution Unit (on spacecraft)
PFM	Proto-Flight Model
PLM	Payload Module
QLF	Quick Look Facility
S/C	Space Craft
SMEC	Spectrometer MEChanism
SPIRE	Spectral and Photometric Imaging REceiver
SRD	Science Requirements Document
SVM	Service Module
TBC	To Be Confirmed
TBD	To Be Determined

References

Applicable Documents

Document Reference	Name	Number/version/date
AD1	Instrument Requirements Document	SPIRE/RAL/N/0034 issue .31 25 May 2000
AD2	FIRST/PLANCK Operations Interface Requirements Document (FOIRD)	SCI-PT-RS-07360 Draft 5 03 May 2000 SPIRE-ESA-DOC-000188
AD3	SPIRE Calibration Requirements Document (TBW)	
AD4	SPIRE Operations Requirements Document (TBW)	

Table B: Applicable Documents

The abbreviations in brackets are used throughout the present document.

Reference Documents

RD1	Instrument Conceptual Design Description (TBW)	
RD2	FIRST/Planck - SPIRE AVM Definition	SPIRE-RAL-COM-000387.1
RD3	SPIRE Instrument CQM Requirements	SPIRE-RAL-NOT-000389.1
RD4	FIRST SPIRE: Optical alignment verification plan	LOOM.KD.SPIRE.2000.001-1
RD5	Operating Modes for the SPIRE Instrument	SPIRE-RAL-DOC-000320.21
RD6	SPIRE Science Requirements Document	Version 0.2 29 March 1999 SPIRE-UCF-DOC-000064

1. Introduction

1.1 Scope

This document describes the sequence of events and procedures leading from the delivery of the instrument sub-systems to the final delivery to ESA of each of the deliverable models of the SPIRE instrument.

1.2 Requirements on the Instrument AIV

The instrument is described in the *Instrument Conceptual Design Description* (RD1) and the requirements the instrument performance and verification are detailed in the *Instrument Requirements Document* (AD1). The primary purpose of the SPIRE AIV is to verify that the Proto-Flight Model of the instrument delivered to ESA is compatible with the requirements of the FIRST mission (launch and operational environment etc) and is capable of carrying out the scientific mission as described in the *SPIRE Science Requirements Document* (RD6).

The AIV of the instrument is also required to provide certain data tables that will enable the operation of the instrument in flight. It is also required to test the procedures to be used to operate the instrument in flight and during system level testing after integration in the satellite – the requirements on these are given in the *FIRST/Planck Operations Interface Requirements Document* (AD2) and the *SPIRE Operations Requirements Document* (AD4). Finally the AIV of the instrument should test the observing modes to be used to take scientific data and provide the calibration tables required to process the data on the ground – the requirements on these come from the *Calibration Requirements Document* (AD3) and the *Operating Modes for the SPIRE Document* (RD5).

This first draft of the document is designed to allow the instrument schedule to be scoped and does not contain formal cross references to the various requirements documents – some of which are yet to be written. A future release will have the full compliance matrix in place and each step will be referenced to its appropriate requirement.

2. Deliverable Models

The deliverable models of the SPIRE instrument are described in AD1. The descriptions are repeated here for information purposes.

AVM – Avionics Model. The IID-A states that this is: "…to validate electronics and software for its interface with the S/C, including anything that exchanges information with, for example, the AOCS. In addition all tasks relevant to SPIRE autonomy shall be verified." We have interpreted this as being a DPU plus a simulator of the DRCU and the cold FPU – the latter is termed the DRCU Simulator.

CQM - Cryogenic Qualification Model. For both the cold FPU and the warm electronics it is assumed that this is built to flight standards, but not necessarily using flight quality electronic components. The performance capabilities of the instrument may be less than the proto-flight model - i.e. fewer pixels in the focal plane arrays, but it will mimic as exactly as possible the thermal, electrical and mechanical properties of the flight instrument and will be capable of under going the full environmental qualification programme.

*PFM – Proto-Flight Model. This will be the instrument model that is intended for flight. It will be built to full flight standards and will only have minor differences in thermal, electrical and mechanical properties to the CQM. It will have the same mechanical, thermal and electrical interfaces to the satellite as the CQM but, may, however, have minor internal design changes compared to the CQM. For instance the bolometer arrays may have many more pixels. The PFM will therefore undergo environmental test to qualification levels for acceptance times (**TBD**) - this applies to both the warm electronics boxes and the cold FPU.*

FS – Flight Spare. The flight spare cold FPU will be made from the refurbished CQM (TBC). The flight spare warm electronics will consist of spare electronics cards.

The requirements on the AVM are discussed in more detail in RD2 and the requirements on the CQM in RD3. For the purposes of the present document it is assumed that the AVM is as described in this section with TBD functionality and that the CQM has all sub-systems present with the functionality described in RD3.

3. Instrument Deliverables

Figure 3-5 is a graphical representation of the deliverable items that are required for the instrument integration for all models of the cold FPU. The details for the production of these deliverables are given in the appropriate sub-system and development plans and the Instrument Development Plan (AD2) and are not discussed further in the present document. The responsible institutes for each sub-system are detailed in the Instrument Product Tree – AD3. Note that only one AIV facility is required for all three cold FPU models.

Figure 3-1 shows the deliverables required for the avionics model of the DPU which will be used both for the testing of the CQM FPU and will, ultimately be delivered to ESA as part of the instrument AVM together with a DRCU simulator and a set EGSE. Figure 3-2 shows the deliverables for the electronics to be used to test the CQM FPU – note here that the simulators and EGSE systems are delivered only once and are presumed to be used again for the electronics for the PFM and FS. Figure 3-3 shows the deliverables for the electronics to be used to test the PFM FPU. These will initally consist of the QM versions of the DRCU, the interconnect harness and the DPU. At a later stage, and before instrument calibration can commence, the PFM versions of the warm electronics must be delivered. Figure 3.4 shows the deliverables for the electronics to be used to test the FS instrument. It is anticipated that these will consist of cards built to flight standards inserted into the QM boxes and backplanes.

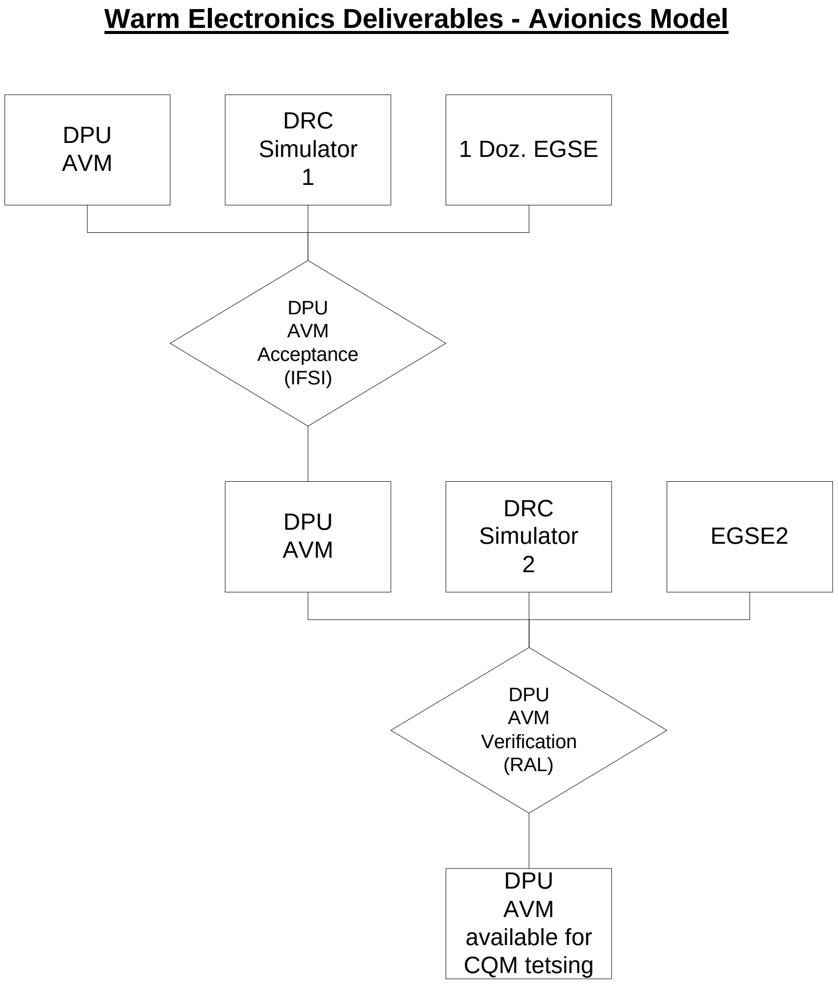

Figure 3-1: Deliverable sub-systems for the Avionics Model AIV.

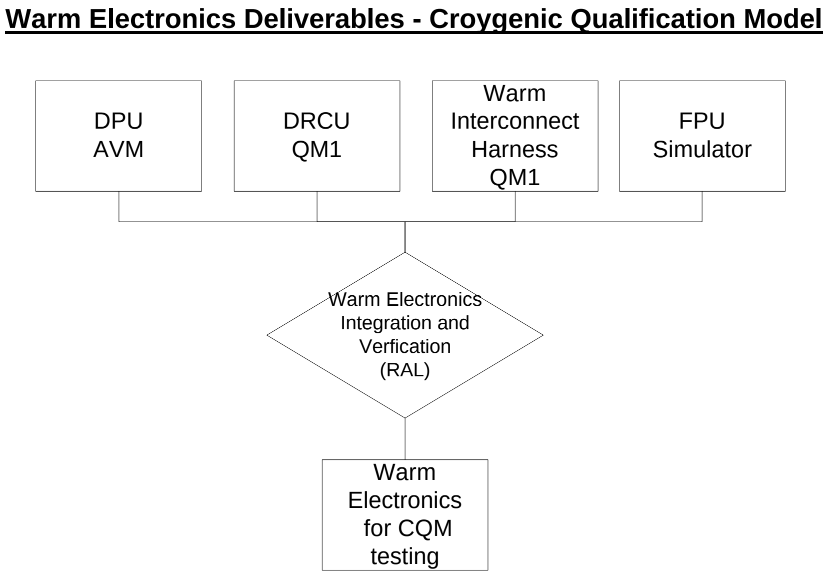

Figure 3-2: Deliverable sub-systems for the warm electronics for CQM AIV

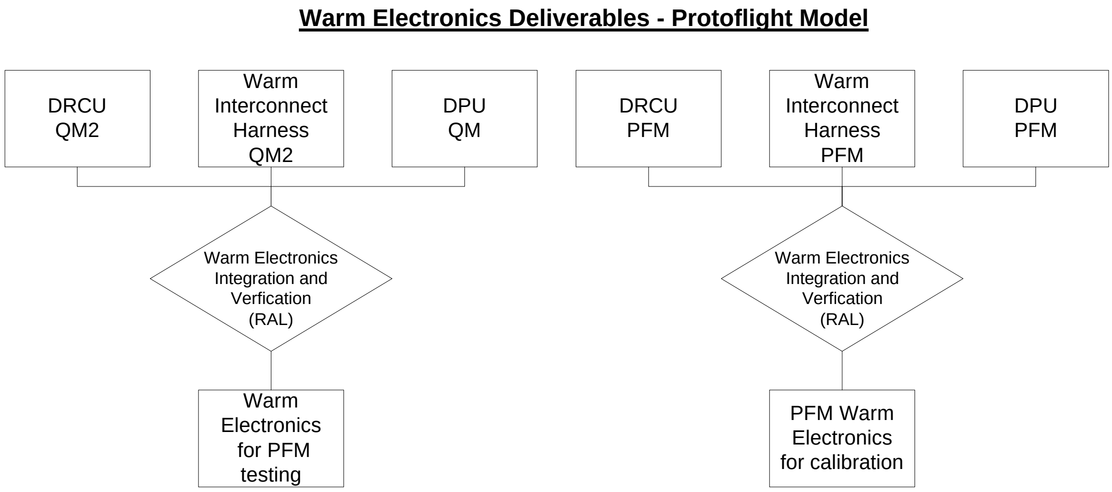

Figure 3-3: Deliverable sub-systems for the warm electronics for PFM AIV

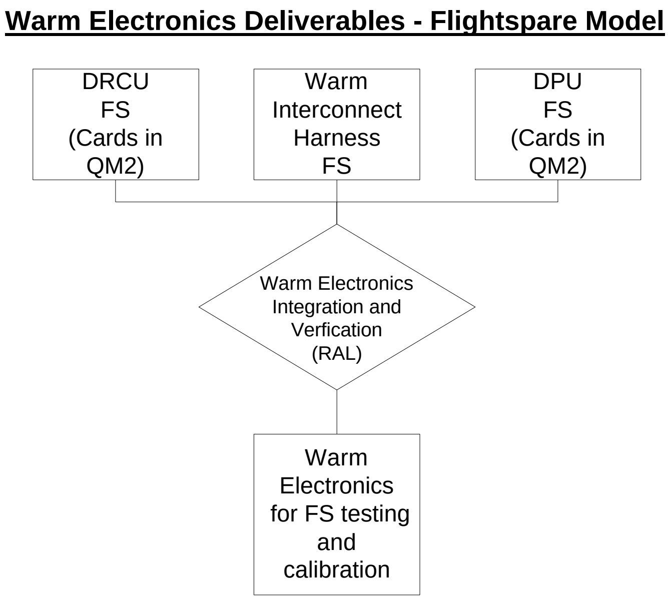

Figure 3-4: Deliverable sub-systems for the warm electronics for FS AIV

Instrument deliverables for all models

Figure 3-5: Deliverable sub-systems for the SPIRE Instrument level AIV for all cold FPU models

4. WARM ELECTRONICS AIV

4.1 Overview

Production of the warm electronics units for SPIRE is phased differently to the cold FPU and JFET Box production. This is dictated by the resources available and complex nature of the interfaces between the sub-systems and the warm electronics. In this we describe section the assembly and integration of the units that go to make up the warm electronics used to test each instrument model and those which will be delivered to ESA.

4.2 AVM Warm Electronics

4.2.1 Capabilities

The AVM warm electronics consists of the AVM model of the DPU; a set of EGSE and a simulator of the DRCU and cold FPU. It is intended that these will be delivered to ESA.

The DPU will have the full functionality of the flight version but it will be built with commercial grade parts and will not have redundant systems fitted. It will be identical in external form and fit to the flight unit. This unit will also be used for the testing of the CQM cold FPU and JFET box.

The DRCU simulator will be a computer with interface cards to the DPU that is capable of receiving commands from the DPU and returning realistic data to mimic the operation of the DRCU; cold FPU and JFET box. Several DRCU simulators will be required at different institutes.

The functionality of the EGSE to be delivered with the AVM is TBD.

4.2.2 Outline Integration and Verification

Figure 3-1 shows the indicative order of assembly, integration and verification for the AVM DPU and the associated EGSE and DRCU simulator. More detail on the steps to be followed is given here.

1. DPU acceptance at IFSI
    - 1.1. The DPU is delivered from the contractor to IFSI
    - 1.2. The DRCU simulator #1 is delivered to IFSI from Stockholm
    - 1.3. The EGSE #1 is delivered to IFSI from RAL (TBC)
    - 1.4. The units are connected and basic interface checks are carried out to ensure compatibility between the DPU; DRCU simulator and the EGSE
    - 1.5. The DPU acceptance procedure is carried out to ensure the compatibility of the unit as delivered from the manufacturer with the SPIRE instrument requirements and interface specification
    - 1.6. If the DPU is accepted then it is prepared and shipped to RAL. The DRCU simulator #1 and the EGSE #1 remain at IFSI
2. DPU verification at RAL
    - 2.1. The DRCU simulator #2 is delivered to RAL from Stockholm
    - 2.2. EGSE#2 is already at RAL
    - 2.3. The DPU is received from IFSI
    - 2.4. The DPU is integrated with the EGSE and DRCU simulator and basic interface checks are carried out.

2.5. The AVM verification procedure is carried out.
2.6. The DPU AVM is now available for use with the warm electronics to be used with the instrument CQM. This DPU will also be delivered to ESA together with the DRCU simulator #3 and the EGSE#3 to form the Instrument AVM.

4.3 Warm Electronics for instrument CQM Testing

4.3.1 Capabilities

The warm electronics for the CQM testing consist of the DPU AVM and a qualification model of the DRCU that has full flight functionality but will be built with commercial grade parts and will not have any redundancy. The QM1 DRCU will be identical in external form and fit to the flight unit. An engineering model of the warm interconnect harness will also be used. Again this will have external form and fit identical to the flight unit but will be built with commercial grade parts. In order to verify the function of the warm electronics for the CQM testing a simulator of the cold FPU and JFET box is required to give realistic responses to the DRCU in the absence of the real sub-systems. This FPU simulator is intended to be as passive as possible, i.e. resistors in place of JFETs; coils; thermistors etc. Only the output from the SMEC position encoder may have to provide some active return in the form of a sinusoidal signal.

4.3.2 Outline Integration and Verification

Figure 3-2 shows the indicative order of assembly, integration and verification for the AVM DPU; the QM1 DRCU; the QM1 warm interconnect harness and the associated EGSE and FPU simulator. More detail on the steps to be followed is given here.

1. Warm electronics verification at RAL
   1.1. The FPU simulator; the DRCU and the warm interconnect harness will be delivered to RAL from CEA
   1.2. The FPU simulator; the DRCU and the warm interconnect harness will be integrated with the DPU AVM and EGSE#2 and basic interface checks carried out
   1.3. The warm electronics verification procedures will be carried out
   1.4. The warm electronics is now available for integration with the cold FPU and JFET box.
   1.5. This set of electronics, including the FPU simulator, will be delivered to ESA as part of the instrument CQM.

4.4 Warm Electronics Qualification Model

4.4.1 Capabilities

The QM electronics consists of the qualification model DPU; the second qualification model DRCU and the second qualification model warm interconnect harness. These are identical in function; form and fit to the flight units. They will be built to flight standards with some parts in both the DPU and DRCU being "extended range" or commercial grade rather than flight grade. The DPU QM will undergo full environmental and EMC (TBC) testing at IFSI before delivery. The DRCU QM2 will undergo full environmental and EMC testing at CEA before delivery. As the QM FPU simulator has been delivered to ESA as part of the instrument CQM, another one is required for testing this set of electronics.

4.4.2 Outline Integration and Verification

Figure 3-3 shows the indicative order of assembly, integration and verification for the QM DPU; the QM2 DRCU and the QM2 warm interconnect harness and the associated EGSE and FPU simulator. More detail on the steps to be followed is given here.

1. Warm electronics verification at RAL
    1.1. The FPU simulator; the DRCU and the warm interconnect harness will be delivered to RAL from CEA
    1.2. The DPU will be delivered to RAL from IFSI
    1.3. The FPU simulator; the DRCU and the warm interconnect harness will be integrated with the DPU and EGSE#2 and basic interface checks carried out
    1.4. The warm electronics verification procedures will be carried out
    1.5. The warm electronics is now available for integration with the cold FPU and JFET box.
    1.6. This set of electronics will be used to carry out the majority of instrument PFM tests, however they are not intended for flight and will not be delivered to ESA.

4.5 PFM Warm Electronics

4.5.1 Capabilities

The PFM electronics consist of the flight models of the DRCU; the warm interconnect harness and the DPU. These are the units intended for flight and have, naturally all the functions required including redundancy and are fully compliant with the satellite interface requirements. The DRCU; warm interconnect harness and the DPU will have been through environmental acceptance testing before delivery to RAL.

4.5.2 Outline Integration and Verification

Figure 3-3 shows the indicative order of assembly, integration and verification for the QM DPU; the QM2 DRCU and the QM2 warm interconnect harness and the associated EGSE and FPU simulator. More detail on the steps to be followed is given here.

1. Warm electronics verification at RAL
    1.1. The DRCU and the warm interconnect harness will be delivered to RAL from CEA
    1.2. The DPU will be delivered to RAL from IFSI
    1.3. The FPU simulator; the DRCU and the warm interconnect harness will be integrated with the DPU and EGSE#2 and basic interface checks carried out
    1.4. The warm electronics verification procedures will be carried out
    1.5. The warm electronics is now available for integration with the cold FPU and JFET box.
    1.6. This set of electronics will be used to carry out the calibration and functional performance tests on the PFM instrument. They will be delivered to ESA as part of the PFM instrument.

4.6 FS Warm Electronics

4.6.1 Capabilities

It is intended to provide flight spare electronics at board level only. In order to test the electronics the boards will be assembled into the qualification model DRCU and QM DPU frames (QM2 and QM respectively). Once assembled into the appropriate frames that FS boards will have fully flight like function and external form and fit. The QM2 warm interconnect harness will be used for flight spare testing and there will be no FS warm interconnect harness. The boards will undergo environmental acceptance testing in the qualification model boxes. It is assumed that the QM2 harness remains at RAL.

4.6.2 Outline Integration and Verification

Figure 3-4 shows the indicative order of assembly, integration and verification for the QM DPU; the QM2 DRCU and the QM2 warm interconnect harness and the associated EGSE and FPU simulator. More detail on the steps to be followed is given here.

1. Warm electronics verification at RAL
   - 1.1. The DRCU boards assembled into the QM2 frame will be delivered to RAL from CEA
   - 1.2. The DPU boards assembled into the QM frame will be delivered to RAL from IFSI
   - 1.3. The FPU simulator; the DRCU and the warm interconnect harness will be integrated with the DPU and EGSE#2 and basic interface checks carried out
   - 1.4. The warm electronics verification procedures will be carried out
   - 1.5. The warm electronics is now available for integration with the cold FPU and JFET box.
   - 1.6. This set of electronics will be used to carry out the calibration and functional performance tests on the FS instrument. The boards within the electronics will be available to replace PFM boards in the PFM instrument in the event of failures during system level AIV.

5. STM/CQM AIV

5.1 Capabilities

The requirements and consequent capabilities of the CQM instrument are discussed in RD3. In summary the FPU will have all sub-systems as flight-like except for the detectors where the number of active detectors will be far fewer than in the flight instrument.

5.2 Outline Assembly, Integration and Verification

Figure 3-5 shows the indicative order of assembly and integration of the CQM. In this section the order of assembly of the cold FPU sub-systems is given. This is intimately connected to the structure integration procedure and the alignment plan and is subject to revision as detailed design of the structure evolves. Note that the AIV plan outlined here calls for the build and test of an instrument Structural Thermal Model (STM). This is not an entirely separate model of the instrument as it will consist of the CQM structure and optics with mass dummies for the other sub-systems. It is rather to allow for a verification of the structural design by conducting a warm vibration and a cool down early on in the CQM AIV.

1. Integration and Verification of STM and Optical Alignment.
   1.1. All the structural elements – including the thermal straps; the structure thermometry and the mirror mounts are assembled (to be detailed in the structure integration procedure)
   1.2. Mechanical metrology is carried out to verify the positions of the mirror interfaces
   1.3. The mirrors and optical dummies are integrated and the optical alignment verified according to the Alignment Plan (RD4 sections 3.2.3 and 3.2.4 and 4.2.3 and 4.2.4). The optical alignment may also include verification of the stability of the alignment during structural integration/de-integration.
   1.4. The sub-system mass dummies are integrated and the instrument is instrumented for vibration test. The structure is re-integrated as appropriate – this is now the STM.
   1.5. The optical alignment is verified (RD4 sections 3.2.7 and 4.2.7)
   1.6. A warm vibration programme is carried out.
   1.7. Any post vibration inspection; verification or functional testing is carried out (see comments below)
   1.8. The optical alignment is verified as before and the full warm alignment procedure is completed (RD4 sections 3.2.5 through 3.2.7. and 4.2.5 through 4.2.7). This will include various de-integration and re-integration procedures. At the end of the warm alignment verification the STM will be fully integrated as before the vibration test
   1.9. The STM could be baked out this point
   1.10. The optical alignment is verified
   1.11. The STM is integrated into the test cryostat
   1.12. The STM is cooled to operational temperature (TBC). During this test the time taken for various parts of the instrument to cool can be checked as verification of the thermal model calculations. It may also be advantageous to have heaters placed in strategic locations without in the structure to verify thermal transfer characteristics of the instrument.
   1.13. The optical alignment is verified cold.
   1.14. The STM is warmed up
   1.15. The STM is de-integrated and mass dummies removed ready for CQM integration.

   Bits forgotten need thinking about – what about the harnesses; what about the RF filter modules – these >could< both be put into the STM and get vibrated – it would also mean that the harnesses were already present when it came to CQM integration. A functional check procedure on the harnesses and Filter modules would be required and the subsystem mass dummies would need something to look like connector interfaces.

2. Integration of CQM FPU (suggested order of sub-system integration (TBC))
   2.1. If not already in (see above) then integration of RF Filter modules and interconnect harnesses.
   2.2. 2-K dichroics
   2.3. Detector integration and alignment verification (HOW-optical/mass dummies still needed?)
   2.4. 2-K Filter integration

- 2.5. SMECm integration and alignment verification (HOW ditto)
- 2.6. SMECp integration
- 2.7. BSM integration at alignment verification (HOW)
- 2.8. Shutter integration
- 2.9. Spectrometer calibrator integration
- 2.10. Cooler integration
- 2.11. Beam splitters; baffles with associated filters and filters integration
- 2.12. Structure re-integration and any mechanical verification

It is assumed that the JFET Box comes ready assembled.

3. Cold FPU and JFET Box integration into test cryostat
   - 3.1. Details to be given in the instrument integration procedures – one assumes continuity checks etc as the harnesses are connected.

4. Cold FPU; Warm Electronics and EGSE integration
   - 4.1. The Warm Electronics have previously been integrated with the EGSE and Quick Look Facility as part of the Warm Electronics integration procedures – see section 4. Now the cold FPU and JFET Box are integrated via the test interconnect harness.
   - 4.2. Basic interface checks are carried out to ensure correct connection of harnesses and electronics units.

5. Warm functional check
   - 5.1. A full warm functional check of the system will be carried to ensure instrument and cryo-harness integrity; sub-system operation (if possible at ambient pressure and temperature) and system operations (commanding, data collection etc.) prior to cool down.

6. Cool Down
   - 6.1. The instrument is cooled to operating temperature slowly with careful monitoring of all temperature channels – this first cool down of the entire cold FPU and JFET Box is used to verify the maximum rate at which the cool down can take place.

7. Preliminary Cold Functional Checks
   - 7.1. Basic interface checks are carried out to ensure integrity of harnesses
   - 7.2. A cold functional check of all sub-systems is carried out to ensure preparedness for full operation (heaters still working; signals returned from position sensor; coils taking current etc)

8. Full functional Check Out and Thermal Balance Checks
   - 8.1. If the preliminary functional checks are satisfactory then each sub-system will undergo full functional tests for each of its defined operating modes
   - 8.2. This will include recycling the cooler for the first time and the instrument will now be capable of operation at all of its correct temperatures. As part of the functional characterisation the thermal balance of the instrument will be verified in each of its operating modes.

9. Instrument performance tests

9.1. A scientific performance check will be carried out on the instrument. This is designed to test for a) problems arising with operation of the sub-systems in the fully integrated instrument and b) to test critical performance characteristics that are likely to change following the cold vibration test.

10. Warm up and warm functional checks
10.1. The cold FPU and JFET box will be warmed to ambient temperature
10.2. A full warm functional check of the system will be carried to ensure instrument integrity and to give a baseline for the instrument vibration tests.
10.3. The cold FPU (and JFET box? if this has been cold vibrated before delivering it won't need to come out? do we need to do both together?) will be removed from the cryostat and prepared for transport to the cold vibration facility.

11. Vibration
11.1. The cold FPU will be transported to the cold vibration facility and integrated into the facility.
11.2. The cold FPU will be vibrated at the appropriate launch configuration and temperatures. It will (probably) be a three axis shake with a short warm functional test between each axis. Suitable check out equipment (DVM!) will be required for the warm functional tests.
11.3. Following the test programme the cold FPU will be packed and transported back to RAL.

12. Instrument re-integration and warm functional check:
12.1. The cold FPU will be re-integrated into the test cryostat
12.2. A warm functional check will be carried out to verify sub-system integrity and operation following vibration.

13. Cool down
13.1. The instrument will be cooled to operating temperature at the nominal rate (verified in step 6)

14. Cold functional test and performance verification
14.1. A full cold functional test will be done to ensure instrument integrity and to re-characterise the sub-systems following vibration.
14.2. The short scientific performance check carried out prior to vibration will be repeated to test for changes in critical instrument performance characteristics following vibration.

15. Full performance verification
15.1. The optical and scientific performance of the instrument will be fully characterised to verify the design against the instrument requirements. These tests are TBD but are likely to include tests of the instrument operation as a function of interface temperatures; straylight; microphonics etc.

16. Characterisation of the QM electronics with CQM FPU
16.1. All testing so far described will be carried out using the AVM/EM warm electronics units. These are built with commercial grade components and are not

capable of undergoing environmental test. If the QM Warm Electronics units are delivered in time then they will be integrated with the cold FPU and performance tests repeated. Further testing may also be carried out – such as thermal range characterisation and conducted susceptibility where the presence of the real cold FPU rather than a simulator is though to be likely to affect the behaviour of the electronics.

17. Cold Functional Check
    17.1. Prior to the final warm up a cold functional check will be done to provide the baseline operational characteristics of the instrument for the satellite system tests.

18. Warm up and warm functional check
    18.1. The cold FPU and JFET box will be warmed to ambient temperature
    18.2. After warm up a final warm functional check will be done to provide a baseline for the satellite system tests.
    18.3. The cold FPU and JFET Box will be removed from the cryostat.

19. Mass properties and preparation for transport
    19.1. The mass properties of the instrument components will be measured.
    19.2. The instrument components will be placed in the transportation containers and delivered to the ESA prime contractor for PLM integration and CQM systems tests.

6. PFM AIV

6.1 Capabilities

The PFM FPU and JFET Box must be fully compliant with the Instrument Requirements Document. The electronics used to test the PFM FPU and JFET Box are initially the Qualification Models of the DRCU and DPU. However, in order to fully calibrate the instrument prior to integration in the satellite the PFM electronics units must be integrated with the FPU and JFET box and the calibration procedures carried out with the full proto-flight instrument.

6.2 Outline Assembly and Integration and Verification

Figure 3-5 shows the indicative order of assembly and integration of the PFM. In this section the order of assembly of the cold FPU sub-systems is given. This is intimately connected to the structure integration procedure and the alignment plan and is subject to revision as detailed design of the structure evolves.

1. Structure Integration and Optical Alignment.
   - 1.1. All the structural elements – including the thermal straps; the structure thermometry and the mirror mounts are assembled (to be detailed in the structure integration procedure)
   - 1.2. Mechanical metrology is carried out to verify the positions of the mirror interfaces
   - 1.3. The mirrors and optical dummies are integrated and the optical alignment verified according to the Alignment Plan (RD4).
   - 1.4. The structure and mirrors could be baked out this point
   - 1.5. The optical alignment stability is verified
   - 1.6. The structure and mirrors are integrated into the test cryostat
   - 1.7. The structure is cooled to operational temperature (TBC).
   - 1.8. The optical alignment is verified cold.
   - 1.9. The structure is warmed up
   - 1.10. The optical/mass dummies are de-integrated

2. Integration of PFM FPU (suggested order of sub-system integration (TBC))
   - 2.1. Integration of RF Filter modules and interconnect harnesses.
   - 2.2. 2-K dichroics
   - 2.3. Detector integration and alignment verification (HOW?)
   - 2.4. 2-K Filter integration
   - 2.5. SMECm integration and alignment verification (HOW ditto)
   - 2.6. SMECp integration
   - 2.7. BSM integration at alignment verification (HOW)
   - 2.8. Shutter integration
   - 2.9. Spectrometer calibrator integration
   - 2.10. Cooler integration
   - 2.11. Beam splitters; baffles with associated filters and filters integration
   - 2.12. Structure re-integration and any mechanical verification

It is assumed that the JFET Box comes ready assembled.

3. Cold FPU and JFET Box integration into test cryostat
   3.1. Details to be given in the instrument integration procedures – one assumes continuity checks etc as the harnesses are connected.

4. Cold FPU; Warm Electronics and EGSE integration
   4.1. The Warm Electronics have previously been integrated with the EGSE and Quick Look Facility as part of the Warm Electronics integration procedures. Now the cold FPU is integrated via the test interconnect harness.
   4.2. Basic interface checks are carried out to ensure correct connection of harnesses and electronics units.

5. Warm functional check
   5.1. A full warm functional check of the system will be carried to ensure instrument and cryo-harness integrity; sub-system operation (if possible) and system operations (commanding, data collection etc.) prior to cool down.

6. Cool Down
   6.1. The instrument is cooled to operating temperature
   6.2. Basic interface checks are carried out to ensure integrity of harnesses

7. Cold Functional Test
   7.1. Each sub-system will undergo full functional tests for each of its defined operating modes

8. Pre-Vibration Instrument performance tests
   8.1. A scientific performance check will be carried out on the instrument. This is designed to test for a) problems arising with operation of the sub-systems in the fully integrated instrument and b) to test critical performance characteristics that are likely to change following the cold vibration test.

9. Warm up and warm functional checks
   9.1. The cold FPU and JFET box will be warmed to ambient temperature
   9.2. A full warm functional check of the system will be carried to ensure instrument integrity and to give a baseline for the instrument vibration tests.
   9.3. The cold FPU (and JFET box? if this has been cold vibrated before delivering it won't need to come out? do we need to do both togther?) will be removed from the cryostat and prepared for transport to the cold vibration facility.

10. Vibration
   10.1. The cold FPU will be transported to the cold vibration facility and integrated into the facility.
   10.2. The cold FPU will be vibrated at the appropriate launch configuration and temperatures. It will (probably) be a three axis shake with a short warm functional test between each axis. Suitable check out equipment (DVM!) will be required for the warm functional tests.
   10.3. Following the test programme the cold FPU will be packed and transported back to RAL.

11. Instrument re-integration and warm functional check:
    - 11.1. The cold FPU will be re-integrated into the test cryostat
    - 11.2. A warm functional check will be carried out to verify sub-system integrity and operation following vibration.

12. Cool down
    - 12.1. The instrument FPU and JFET box will be cooled to operating temperature

13. Cold functional test and performance verification
    - 13.1. A full cold functional test will be done to ensure instrument integrity and to re-characterise the sub-systems following vibration.
    - 13.2. The short scientific performance check carried out prior to vibration will be repeated to test for changes in critical instrument performance characteristics following vibration.

14. Full performance verification
    - 14.1. The optical and scientific performance of the instrument will be fully characterised to verify the design against the instrument requirements. These tests are TBD but are likely to include tests of the instrument operation as a function of interface temperatures; straylight; microphonics etc.
    - 14.2. During this period the data and procedures required for the flight operations; the Mission database and the various calibration tables for processing the data will be produced and/or tested. The requirements on what is to be provided are given in AD2, AD3 and AD4.

15. Integration of PFM Warm Electronics
    - 15.1. All testing so far described will be carried out using the QM warm electronics units (see section 4). However, in order to provide the correct calibration tables for flight operations, the PFM instrument must be tested and characterised as a single integrated unit.
    - 15.2. The PFM Warm Electronics will be integrated with the cold FPU and JFET Box and interface checks carried out.

16. PFM Cold Functional Tests
    - 16.1. The integrated PFM instrument will be fully functionally characterised to provide the final operational data tables as required by the instrument operations (given in AD2 and AD4)

17. PFM Instrument Calibration
    - 17.1. The procedures required to provide the instrument calibration tables as specified in AD3 will be carried out on the integrated PFM instrument.

18. Cold Functional Check
    - 18.1. Prior to the final warm up a cold functional check will be done to provide the baseline operational characteristics of the instrument for the satellite system tests.

19. Warm up and warm functional check
    - 19.1. The cold FPU and JFET box will be warmed to ambient temperature

19.2. After warm up a final warm functional check will be done to provide a baseline for the satellite system tests.
19.3. The cold FPU and JFET Box will be removed from the cryostat.

20. Mass properties and preparation for transport
20.1. The mass properties of the instrument components will be measured.
20.2. The instrument components will be placed in the transportation containers and delivered to the ESA prime contractor for PLM integration and PFM systems tests.

7. FS AIV

7.1 Capabilities

The FS FPU and JFET Box will be identical to the PFM. The electronics used to test the FS FPU and JFET Box consist of boards the are identical to the PFM electronics assembled into the qualification model frames.

7.2 Outline Assembly and Integration and Verification

Figure 3-5 shows the indicative order of assembly and integration of the FS. The FS AIV will be identical to the PFM AIV except step 15 which is not required as the calibration and functional characterisation will be carried out with the electronics that will ultimately be used with the flightspare.

There is a logical inconsistency here in fact! If the FS FPU is ever swapped out the corollary is that we also have to swap out the boards in the PFM electronics thus invalidated the acceptance testing which will have to be repeated! In fact we should calibrate and characterise the FS with the PFM electronics if we want to have one to one replacement of the FPUs.